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ASSESSMENT OF ICHTHYOPLANKTON ENTRAINMENT AT BRUCE NGS 'A' - 1985/86

Report No 88-15-K

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ABSTRACT

A pump/net system was used to determine the species composition and abundance of ichthyoplankton entrained at Bruce NGS 'A'during 1985 and 1986. Over the two years of study, burbot, rainbow smelt, alewife and deepwater sculpin accounted for over 90% of the eggs and larvae collected. The diurnal distribution of the dominant species were similar, with the majority of individuals entrained during the evening and early morning hours. Measures of immediate survival and mortality attributable to intake passage and condenser passage for the dominant species entrained were evaluated. At least 70% of the smelt and alewife were dead prior to collection. Intake passage accounted for more mortality among the dominant species than did passage through the station. Immediate survival following entrainment was greatest for alewife and smelt, followed by burbot and deepwater sculpin.

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ASSESSMENT OF ICHTHYOPLANKTON ENTRAINMENT AT BRUCE NGS 'A' - 1985/86

INTRODUCTION

Ichthyoplankton entrainment at power plants using a once-through cooling process and the subsequent impact on fish stocks has received considerable attention. Several models for impact assessment have been suggested (Jinks et al, 1978, Jensen and Hamilton 1982 and MacCall et al, 1983), all of which require a reliable measure or estimate of abundance and mortality for all species entrained. Obtaining these estimates requires a priori knowledge of seasonal succession and density patterns of the species entrained - information which is limited. A reliable sampling procedure is also required which would enable a number of sequential samples to be taken in a relatively short period of time.

Employment of a large volume pump system for entrainment studies has enabled reliable control of the volume of water filtered and minimized sampler induced mortality (Ontario Hydro Research Division Reports 82-312-K and 85-59-K). This system also enables a long series of discrete samples to be collected and therefore provides information on the temporal variability of ichthyoplankton abundance. An understanding of temporal patterns is required since the density of entrained ichthyoplankton has been suggested to vary even within a 12 to 24 hour period and with species of fish entrained (Crippen and Fahmy, 1981 and Kelso and Leslie, 1979, Telki, 1976, respectively).

Information on actual entrainment mortality is also required in order to assess station impact. Previous studies have adopted a "worst-case scenario" by assuming that all ichthyoplankton entrained were alive and subsequently killed by the station (Ontario Hydro Research Division Reports 82-55-K or 83-73-K). Such an approach provides maximum protection to the impacted population and is generally the approach adopted by most assessment studies when crucial information is lacking. Unfortunately, such an approach can lead to costly and potentially unnecessary design of mitigative "solutions" as a counter to postulated "worst-case" scenarios. Information required in order to more realistically assess entrainment losses includes an estimate

of the number of live individuals entrained and killed and an estimate of those that survive entrainment.

The objective of this study was to summarize, for 1985/86, estimates of ichthyoplankton abundance and composition entrained at Bruce NGS 'A'. In addition, measures of "natural" mortality and mortality due to passage from the intake-cap to the intake-forebay, from the intake-forebay to the discharge, and survival were estimated. As well, the diurnal distribution patterns of the dominant species entrained over a 24 hour period were estimated.

METHODS AND MATERIALS

The Bruce 'A' Nuclear Generating Station is located on the east shore of Lake Huron, approximately 17 km south of Port Elgin, Ontario. The station utilizes a once through cooling system and consists of 4 units capable of generating 3300 MWe at maximum capacity. Cooling water is drawn from an offshore submerged intake at a depth of approximately 11 m.

Sampling strategy (ie. procedure, sampling location and analysis) was similar for the two years of study. The pump/net-in-lake system used during both years is described in Ontario Hydro Research Division Report 85-59-K. Samples were collected from the intake-cap, intake-forebay, and discharge channel (Figure 1). The sampling apparatus in the intake-forebay was in a fixed position between units 2 and 3 with samples pumped from a depth of 4.0 m, midway in the width of the channel. An identical apparatus to the intake-forebay apparatus was placed in an anchored boat for the discharge and intake-cap samples. The discharge boat was positioned midway in the discharge channel, approximately 100 m from the end of the cooling water discharge duct. Water samples were drawn from a 1.0 m depth. Samples were collected from an 11 m depth at the intake-cap by coupling 7 PVC pipes (1.5 m long, 10.0 cm diameter) to the intake hose of the pump at the surface of the lake. Water samples at all locations were filtered through a 243 u mesh larval tow net, suspended in the ambient water.

Sampling was initiated earlier in 1986 than in 1985 in an attempt to investigate the possibility that deepwater sculpin larvae are entrained earlier in the year. Samples were collected from the intake-forebay and discharge 4 days per week from April 1 to September 12, 1985 and from March 17 to September 4 in 1986. Intake-cap samples were taken approximately once every 2 weeks. Discharge and intake-cap collections were limited due to pump malfunction. On each sampling occasion, three sequential samples were taken from both the intake-forebay and discharge, 3 hours before and after sunset. Each sample consisted of 28 m^3 of water filtered over a 15-minute period. Estimates of entrainment from the 1985 study used in this study were corrected for volume of water sampled (42 to 28 m^3). Twelve samples were collected on each sampling date.

At all sites, water temperature was monitored for each collection period with a hand held thermometer. The mean condenser water flow for each day was supplied by the station.

Samples were maintained at the collection temperature in 20 L pails prior to sorting. Sorting, enumeration, and identification for eggs and larvae was completed within 60 minutes of collection. Live/dead classification of larvae was also made within this time period. Samples were preserved in 5% formalin and re-sorted the following day; any eggs or larvae found in the second sort were assumed live at the time of collection. Criteria used to classify larvae as dead prior to collection were: a) non-motile, opaque, b) fins or fin buds not definable, c) myomeres not definable, d) gut absent, e) body tissue or outline not well defined. The criteria used to

BRUCE NGS–A COOLING WATER SYSTEM LAYOUT

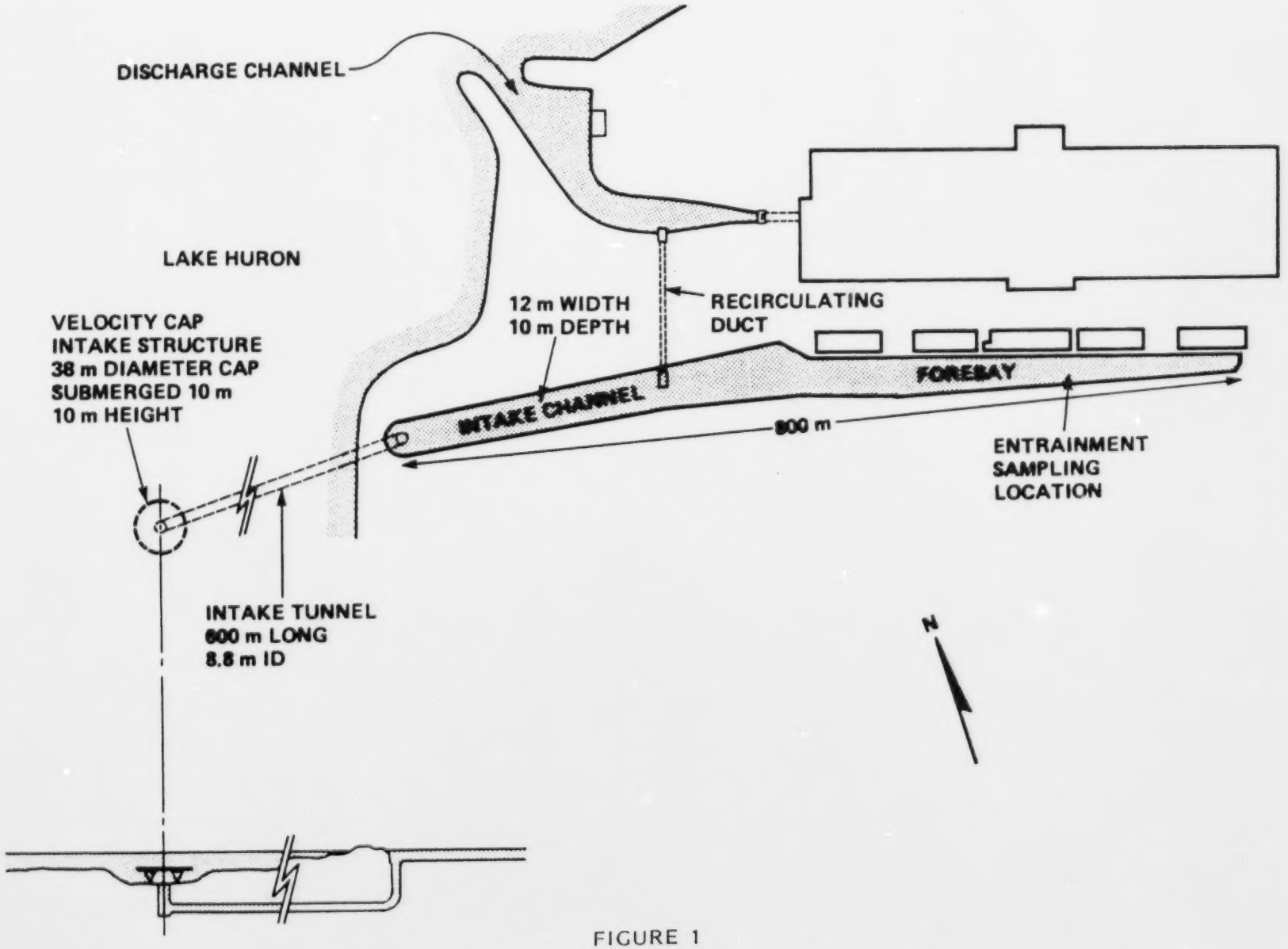

FIGURE 1

define larvae as recently killed (ie. by entrainment and/or sampling) were: a) non-motile, body transparent/translucent, b) gut defined, c) myomeres well defined, d) fins or fin buds well defined, e) body tissue or outline well defined. Total larval length and egg diameter were measured to the nearest 0.1 mm with an ocular micrometer. The stage of larval development and any evidence of damage to the larvae was noted. Eggs were classified as unfertilized or fertilized. Larvae and eggs were preserved in Davidson's B solution.

The diurnal distribution of the entrained ichthyoplankton was determined on occasions by collection of three sequential, 15-minute samples from the intake-forebay every 3 hours for a 24 hour period. Each of these collections coincided with the peak occurrence of each of the previously determined (1985) dominant species. Estimates of latent mortality (larval) was not possible due to difficulties in collecting an adequate sample size of live individuals at any particular time. Those that were collected all died within twenty-four hours following collection. Only information on immediate survival following entrainment for each of the dominant species was obtained.

Mortality due to the sampling device was assumed to be constant throughout the study and has been addressed in an earlier study (Ontario Hydro Research Division 82-312-K). Larval mortality attributable to passage through the submerged intake was determined from the proportion of recently killed larvae collected in the intake-forebay. The difference in recent mortality between the discharge and the intake-forebay was used to determine mortality attributable to passage through the station.

Larval fish densities, expressed as number per 1000 m^3, were calculated as follows:

$$\text{Density (D)} = \frac{\text{number of fish larvae caught}}{\text{volume of water filtered } (m^3)} \times 1000$$

Daily density estimates were based on the average intake catch in the afternoon and evening samples. The daily density estimates were used to calculate the number of larvae entrained weekly through the condenser cooling water system, assuming larvae caught in the intake-forebay were subsequently entrained. Daily entrainment estimates for each week-end were determined by applying catch values for each Thursday to subsequent Friday and Saturday, and Monday values to the previous Sunday.

Daily entrainment = D X condenser water flow (m^3/s) X 86,400 (s)

RESULTS

A total of 4554 eggs and 3204 larvae were collected from the intake-forebay during the two years of study. The majority of the eggs and larvae (85 and 61%, respectively) were collected during the second year of study (Figure 2). The discrepancy in the number of eggs collected between the two years is attributable to a high collection of burbot eggs during 1986 (3555 compared to 364 in 1985). Of the species collected, burbot (*Lota lota*), rainbow smelt (*Osmerus mordax*), alewife (*Alosa pseudoharengus*) and deepwater sculpin (*Myoxocephalus quadricornis*) accounted for greater than 90% of the eggs and larvae collected during the two years of study (Table 1).

Deepwater sculpin larvae were the first to be collected and dominated the catch during March and early April for both years. Larval sculpin entrainment averaged 16.2 X 10^6 larvae during the

two years. Approximately 87% of the larvae were collected in 1986. The size of these larvae were similar between the two years and ranged from 9 to 14 mm in length. No deepwater sculpin eggs were collected over the two years of study.

Burbot eggs dominated samples collected during March and April of both years. Entrainment averaged 149.2 X 10^6 burbot eggs (± 124, SD) and 33.3 X 10^6 larvae (± 0.9, SD) over the two years of study. Burbot larvae were generally present from the end of April until the end of July for both years. These larvae were the smallest of the dominant larvae collected and ranged between 4 and 5 mm in length. The only significant difference between the two years was that ten times the number of burbot eggs were collected in 1986 which again, was probably attributable to the earlier start in sampling.

Rainbow smelt eggs occurred in samples only during May in both years. The dominance of these eggs in samples during May in the second year of study suggests that smelt eggs would have also dominated the catch in 1985 if station operation had not been interrupted. Smelt larvae subsequently appeared in June and July and co-dominated this period with burbot larvae. Smelt entrainment over the two years averaged 2.9 (± 2.7, SD) and 36 (± 13.4, SD) X 10^6 smelt eggs and larvae, respectively. Approximately 64% of the larvae were collected in 1986. Smelt were the largest larvae collected and ranged from 5 to 18 mm.

Alewife eggs were the only eggs collected in the later half of both years of study (July to mid-August). Egg entrainment averaged 9 X 10^6 individuals (± 10.9, SD). In both years of study, alewife larvae first appeared in mid-July and dominated larval entrainment for the duration of the sampling period. Larval alewife entrainment averaged 22.1 X 10^6 individuals (± 2.5, SD) for the two years of study. Larval density between the two years were similar. Larvae ranged in size from 4 to 13 mm.

Other species collected in the intake-forebay samples, in order of decreasing abundance, were walleye (*Stizostedion vitreum*, eggs only), trout-perch (*Percopsis omiscomaycus*), round whitefish (*Prosopium cylindraceum*), slimy sculpin (*Cottus cognatus*), gizzard shad (*Dorosoma cepedianum*) and representatives of the families Cyprindae, Centrarchidae and Percidae. Together these comprised <10% of all eggs and <3% of all larvae collected over the two years. The uncertainty associated with the identification of walleye eggs in 1985 was resolved in 1986. These previous collected eggs, as well as those collected in 1986, were shown to be similar to known walleye eggs.

Generally, most of the dominant larvae were entrained during the evening and early morning hours (1800 - 0300 h) (Figure 3). The exception was alewife where too few individuals were collected to establish any diurnal pattern. The diurnal distribution of smelt and burbot larvae were similar with their increased occurrence only weakly associated to the above time period. The occurrence of deepwater sculpin in samples, however, was strongly related to the evening and early morning hours.

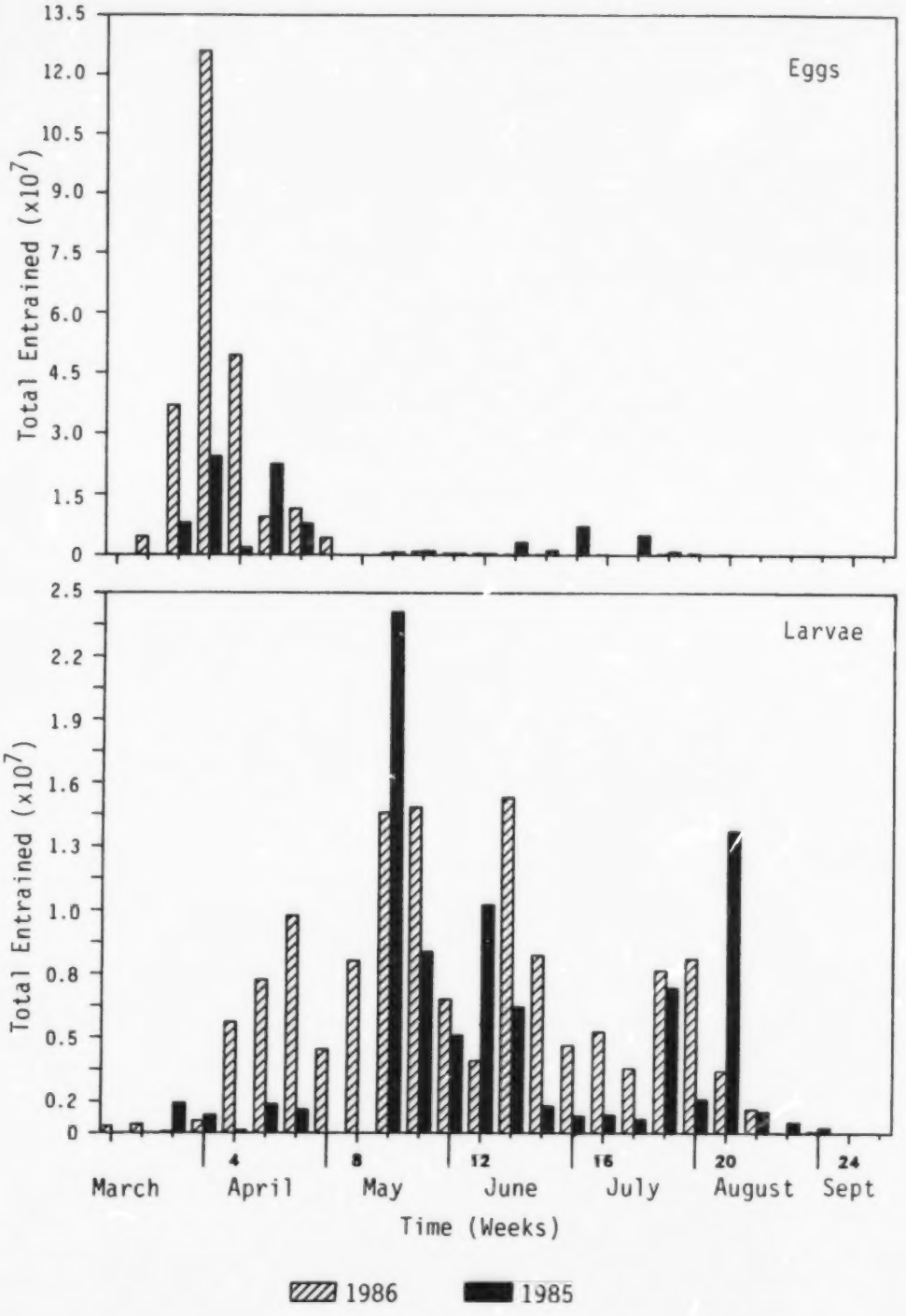

FIGURE 2

A COMPARISON OF THE NUMBER OF FISH EGGS AND LARVAE COLLECTED FROM THE BRUCE NGS 'A' INTAKE-FOREBAY DURING THE 1985 AND 1986 SAMPLING SEASON

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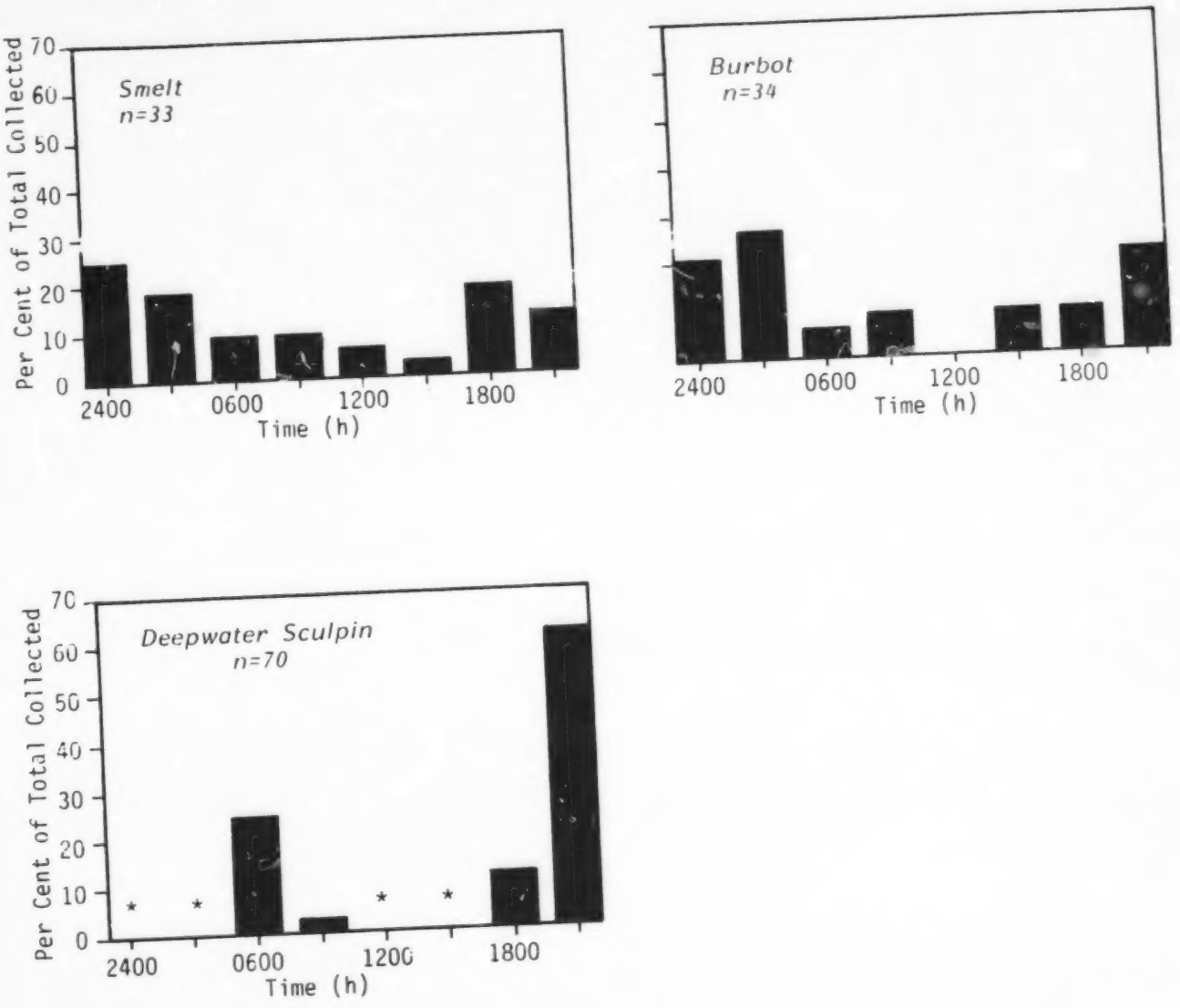

FIGURE 3

DIURNAL DISTRIBUTION OF THE DOMINANT LARVAL FISH SPECIES COLLECTED IN THE BRUCE NGS 'A' INTAKE-FOREBAY. THE NUMBER OF INDIVIDUALS COLLECTED THROUGHOUT THE 24 h SAMPLING PERIOD IS EXPRESSED AS A PER CENT OF THE TOTAL SAMPLED

(Not Sampled)*

TABLE 1

Abundance and Per Cent Composition of Ichthyoplankton Species Collected in the Intake-Forebay of Bruce 'A' NGS, May - September, 1985 and 1986

	Eggs		Larvae		Eggs		Larvae	
	1985	1986	1985	1986	1985	1986	1985	1986
Burbot	364	3555	443	413	54.3	91.5	35.8	21.0
Rainbow Smelt	15	65	381	748	2.2	1.7	30.8	38.0
Alewife	217	30	352	318	32.4	0.8	28.5	16.2
Deepwater Sculpin	0	0	33	410	0.0	0.0	2.7	20.8
Walleye	60	234	0	0	9.0	6.0	0.0	0.0
Trout-Perch	0	0	17	0	0.0	6.0	0.0	0.0
Gizzard Shad	14	0	3	0	2.1	0.0	0.2	0.0
Round Whitefish	0	0	2	22	0.0	0.0	0.2	1.1
Slimy Sculpin	0	0	3	4	0.0	0.0	0.2	0.2
Cyprinidae	0	0	1	10	0.0	0.0	0.1	0.5
Centrarchidae	0	0	1	0	0.0	0.0	0.1	0.0
Percidae	0	0	1	42	0.0	0.0	0.1	2.1

Over the two years of study, between 20 - 28% of the larval deepwater sculpin entrained were judged to be dead prior to collection in the intake-forebay (Table 2). Mortality attributed to intake passage averaged 60% for the 1985/1986 period (Figure 4). The percent survival of live sculpin larvae averaged approximately 16% and varied considerably, <2% (1985) to >30% (1986).

Approximately 31% of the burbot larvae entrained were judged to be dead prior to collection during the two years of sampling (Table 2). Mortality attributed to the intake and condenser passage averaged 80 and 4% respectively for the 1985/86 period (Figure 5). Larval burbot survival following entrainment averaged 16%. Burbot survival between the years varied by approximately 14 per cent.

Of the total number of smelt larvae entrained, approximately 73% (70-76%, 1985/1986) were judged to be dead prior to collection (Table 2). Intake and condenser passage accounted for about 20 and 12% respectively of the mortality of the live larvae entrained (Figure 6). Total mortality between the two years was very similar, 30 to 32%. The remaining 72% were estimated to be alive immediately following entrainment. A similar level of survival was estimated in 1985.

Most of the larval alewife collected (92%) were judged to be dead prior to entrainment (Table 2). Survival immediately following entrainment was similar between the two years (Figure 7).

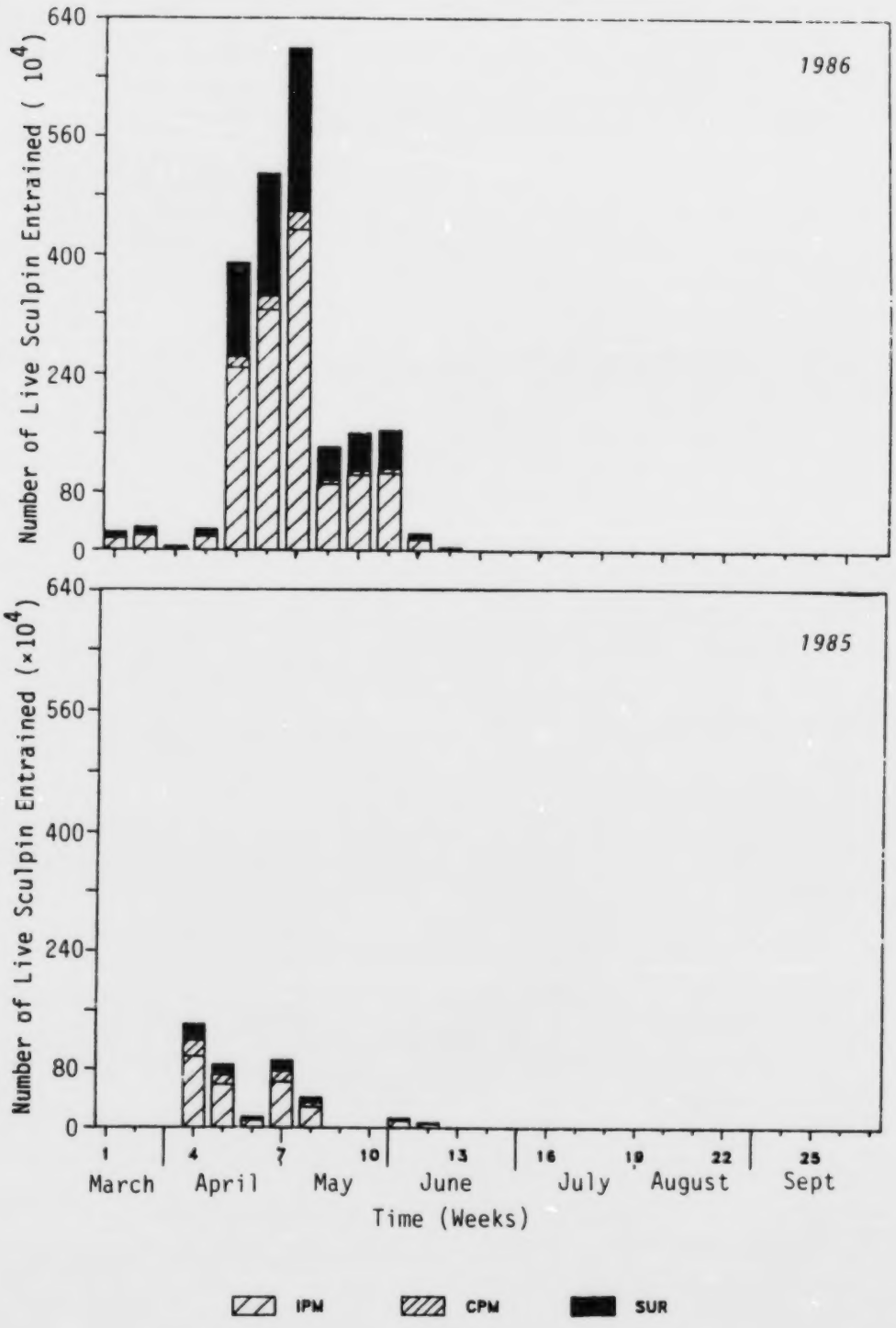

FIGURE 4

A COMPARISON OF THE NUMBER OF DEEPWATER SCULPIN SURVIVING (SUR) AFTER INTAKE AND CONDENSER PASSAGE FOR 1985 AND 1986

(IPM - Intake Passage Mortality, CPM - Condenser Passage Mortality)

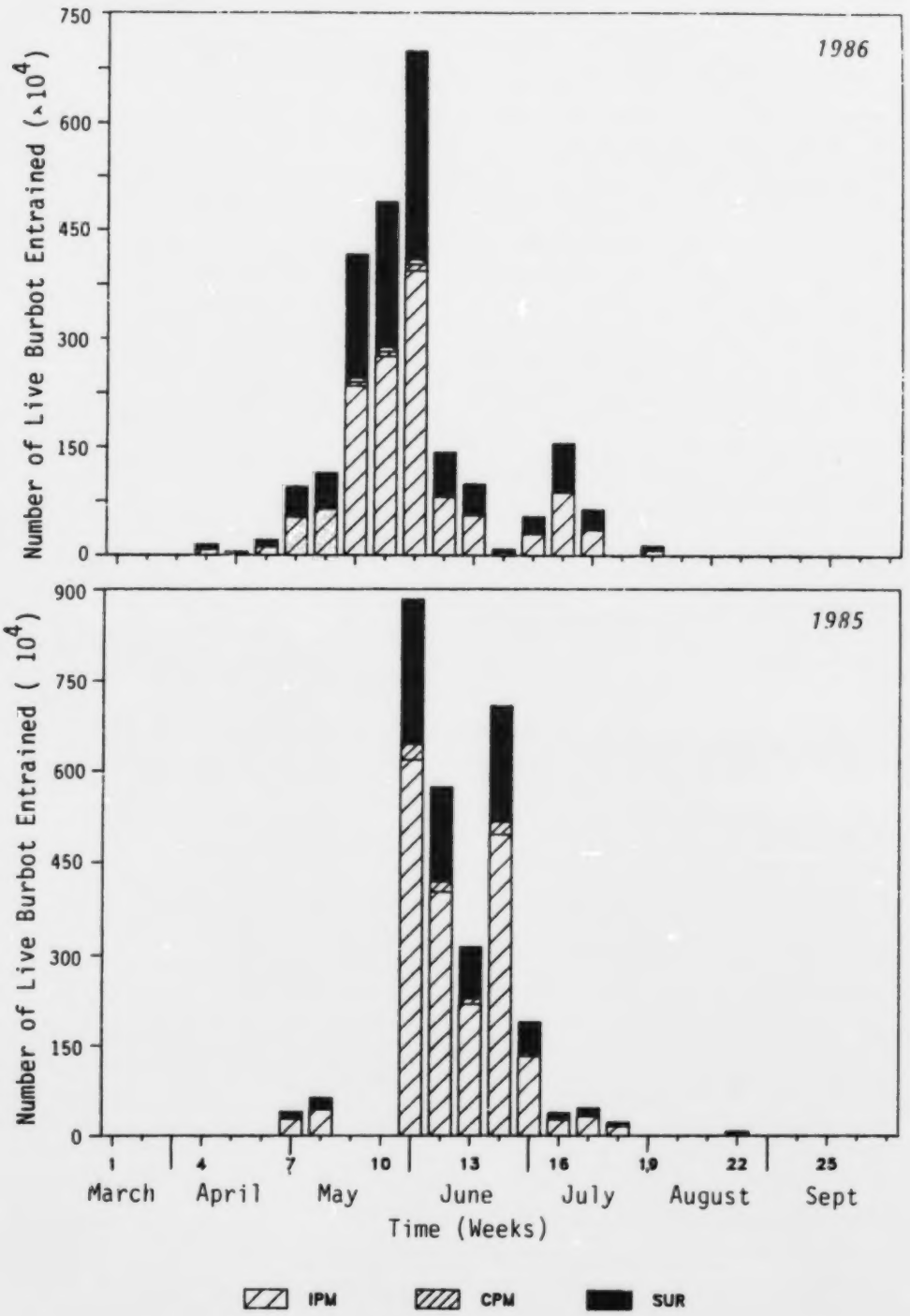

FIGURE 5

A COMPARISON OF THE NUMBER OF BURBOT SURVIVING (SUR) AFTER INTAKE AND CONDENSER PASSAGE FOR 1985 AND 1986

(IPM - Intake Passage Mortality, CPM - Condenser Passage Mortality)

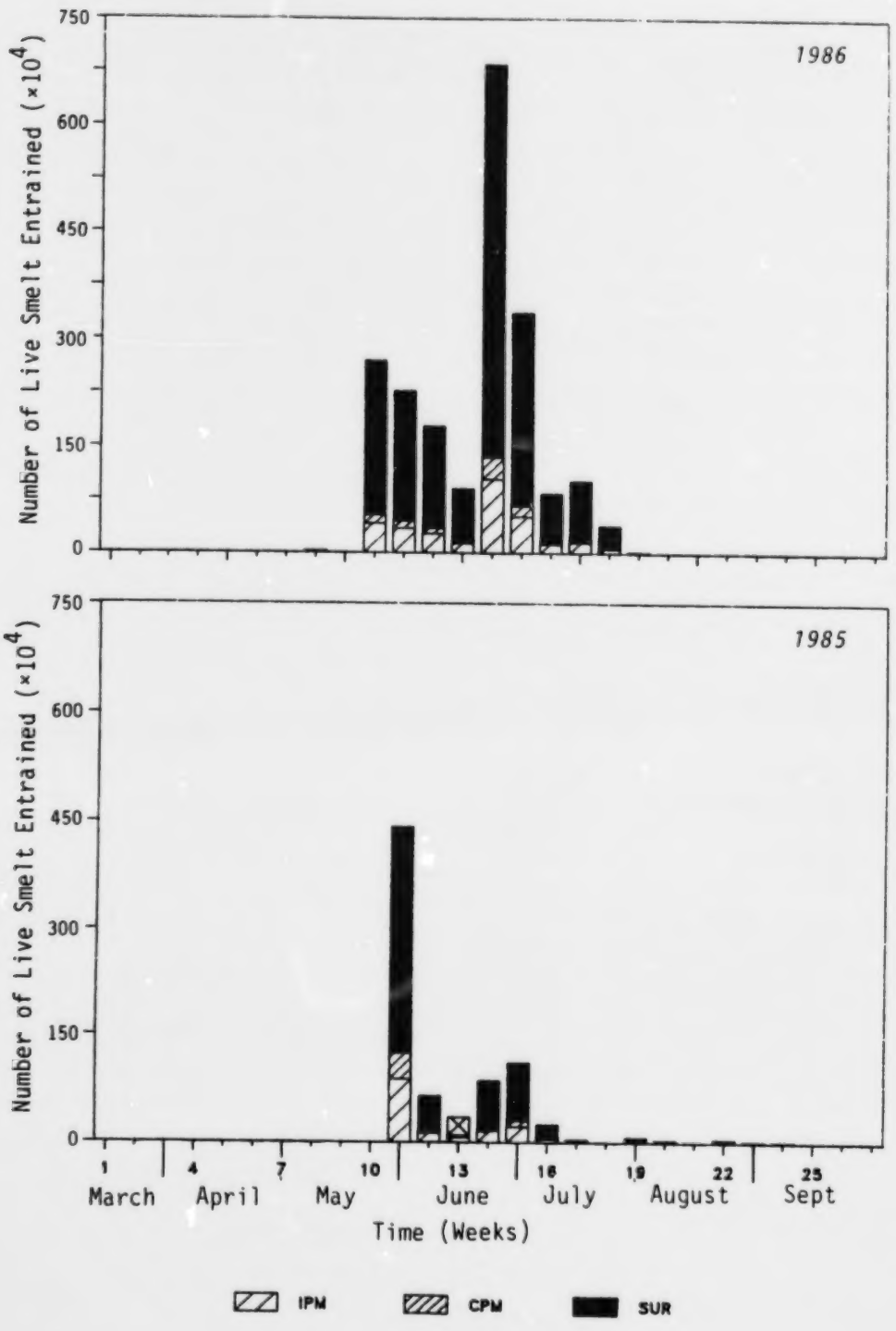

FIGURE 6

A COMPARISON OF THE NUMBER OF SMELT SURVIVING (SUR) AFTER INTAKE AND CONDENSER PASSAGE FOR 1985 AND 1986

(IPM - Intake Passage Mortality, CPM - Condenser Passage Mortality)

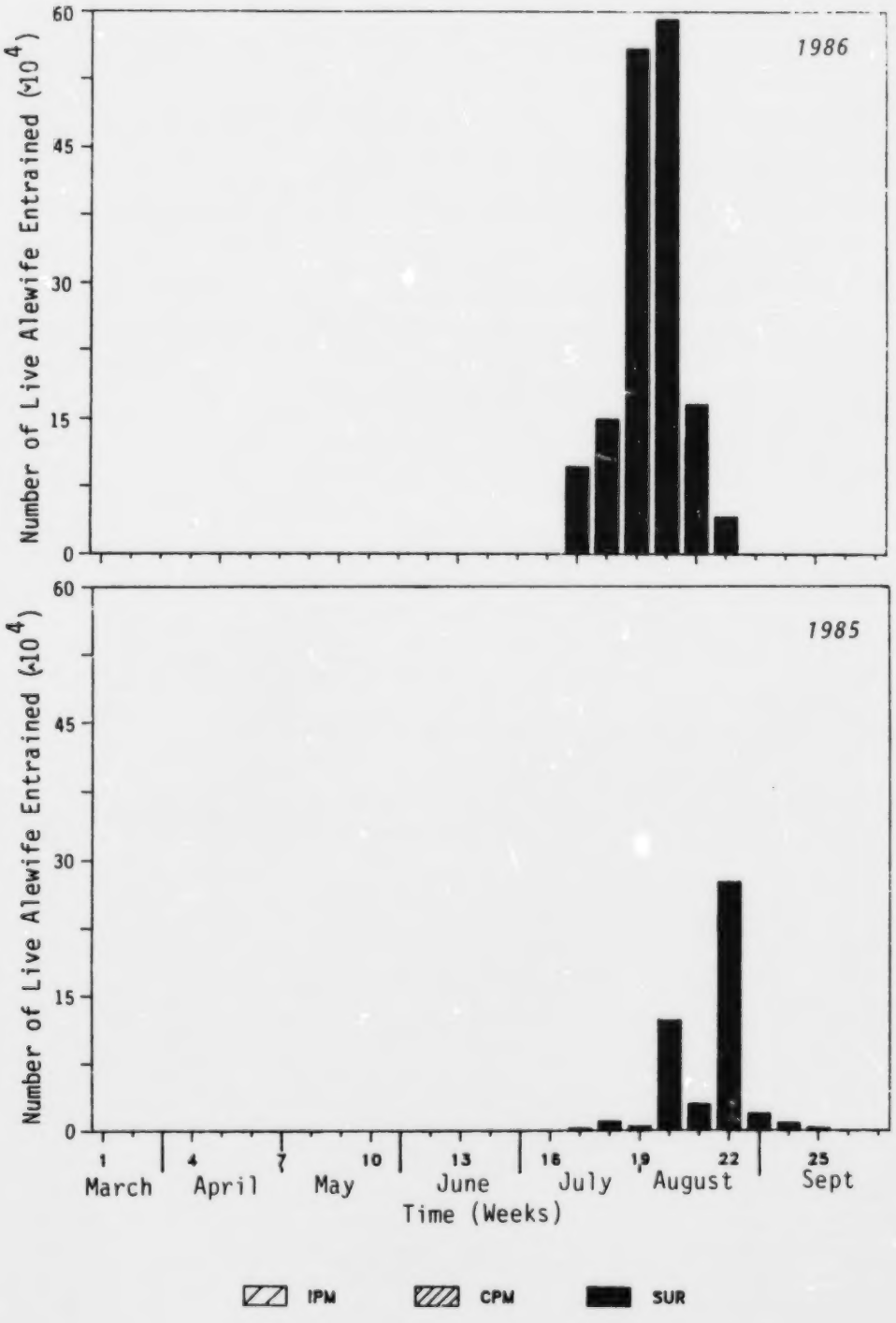

FIGURE 7

A COMPARISON OF THE NUMBER OF ALEWIFE SURVIVING (SUR) AFTER INTAKE AND CONDENSER PASSAGE FOR 1985 AND 1986

(IPM - Intake Passage Mortality, CPM - Condenser Passage Mortality)

TABLE 2

Mortality Estimates (x 10^6), Prior to and Following Entrainment, for Each of the Dominant Ichthyoplankton Species Entrained - Bruce NGS A

	Number of Dead larvae entrained			Number of Live larvae entrained			*Number of larvae killed		
	1985	1986	Mean	1985	1986	Mean	1985	1986	Mean
Deepwater Sculphin	0.81	8.1	4.5	3.3	20	11.6	3.3	7.1	5.1
Burbot	3.1	17.8	10.5	28.6	16.2	22.4	20.6	14.8	17.7
Smelt	18	34.7	26.4	8.6	10.7	9.7	2.7	3.3	3.0
Alewife	3.7	37.1	20.4	0.3	3.3	1.8	0.01	<0.001	<0.001

* immediately following entrainment.

DISCUSSION

The two years of study have shown a greater variety of ichthyoplankton taxa in the intake-forebay than previously reported using conical nets at Bruce NPD (Ontario Hydro Research Division Reports 78-192-K, 82-107-K and 83-96-K, Kelso and Leslie 1979). Species richness over the last two years using the pump/net-in-lake system, however, was similar to the variety of species collected from bottom and surface tows of conical nets conducted out in the lake (Ontario Hydro Research Division Report 88- in draft, Balesic). The variability in species richness from the intake-forebay probably reflects the difference between active (pump) and passive (suspended conical net) sampling methods. Use of conical nets in past entrainment studies, particularly if used as a passive sampling gear in an intake-forebay, may have resulted in an under-estimation of the number of species entrained.

Only the numeric importance of deepwater sculpin and smelt larvae varied over the two years. The increase in numeric importance of the deepwater sculpin larvae during the 1986 entrainment study (21% from 3% of total catch) was probably attributable to the earlier sampling period. It is unlikely, however, that even the 1986 estimate of annual abundance is accurate since all individuals collected had previously undergone the transition from endogenous to exogenous feeding. Deepwater sculpin larvae therefore, may be present well before the month of March. In Lake Michigan, for instance, deepwater sculpin first appeared in early February (Mansfield et al, 1983).

Generally, more larval smelt were collected throughout 1986 than during the 1985 sampling period. Numbers of smelt in 1985, however, would have probably been higher had sampling not been interrupted in May due to the labour dispute (Ontario Hydro Research Division Report 86-190-K).

Entrainment of the dominant larvae was not evenly distributed throughout the day but generally occurred during evening and early morning hours. This is in contrast to earlier studies conducted at Bruce NPD which generally found no difference in total larval density or the density of individual species entrained (Ontario Hydro Research Division Report 78-192-K and Kelso and Leslie 1979). The exception was alewife where more individuals were collected one hour after sunset (Ontario Hydro Research Division Report 78-192-K). The frequency of sampling differed considerably between the present and earlier studies, every three hours to once during the afternoon and night, respectively. The earlier studies may have simply missed the peak entrainment period. Estimates of entrainment reported here are representative of the peak entrainment period. Estimation of actual entrainment from this period can probably be considered more accurate than estimations made from the extrapolation of a few individuals collected outside the peak entrainment period.

The number of larvae collected which were judged dead prior to sampling varied considerably among species but remained relatively constant within species over the two years. The largest portion of dead larvae collected were smelt and alewife. Burbot and deepwater sculpin contributed the least amount. The only species in which considerably more dead were collected during the second year of study was burbot. The majority of these dead larvae were collected very early in the study and were the smallest of the burbot larvae collected. This suggests that these may have just occurred following a hatch of burbot eggs and may simply reflect the typically high "natural" mortality rate of newly hatched larvae.

Of those larvae that were entrained alive, the compression/decompression journey from the intake cap to the intake-forebay accounted for most of the mortality in all of the dominant species. Mortality attributable to condenser passage was generally less than half of that attributable to intake passage. Percent survival for each of the dominant species were similar over the two years, except for deepwater sculpin, where estimates of survival ranged considerably. The survival estimate for the second year of study (>50%) should, however, be considered the more accurate of the two since it is calculated from a much greater sample size than in 1985.

In summary, estimates of species composition and abundance, mortality, and survival were similar for each of the two years. The few exceptions were generally attributable to the expansion of the sampling period during 1986. Examination of the diurnal pattern of each dominant species indicated that the most reliable estimates of ichthyoplankton entrainment would be obtained from studies which include sampling early morning hours of the day.

CONCLUSIONS

1) Rainbow smelt, burbot, alewife and deepwater sculpin accounted for 90% of the eggs and larvae collected in the intake-forebay during 1985 and 1986.

2) Entrainment of rainbow smelt, burbot and deepwater sculpin were more associated with the evening and early morning hours than any other time of the day. Too few individuals of

alewife were collected to establish any diurnal pattern.

3) Greater than 70% of the smelt and alewife larvae collected were considered dead prior to entrainment over the two years of study. Less than 32% of the burbot and deepwater sculpin larvae were judged to be dead prior to entrainment.

4) Of the larvae entrained, intake passage accounted for more mortality than condenser passage. Greater than 50% of the smelt and alewife larvae were estimated to have survived immediately following entrainment. Larval burbot and deepwater sculpin survival following entrainment averaged approximately sixteen per cent.

ACKNOWLEDGEMENTS

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